High Resolution Model Simulations for IFloodS, MC3E, OLYMPEX, LPVEx, and C3VP

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Objective

To use measurements from Global Precipitation Measurement (GPM) Ground Validation (GV) field campaigns (C3VP, MC3E, LPVEx, IFloodS and IPHEX) to evaluate performance of the NASA cloud resolution models.

To conduct real time forecast (MC3E, IFloodS, and IPHEX) using NU-WRF.

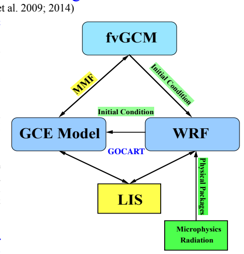
To validate the Goddard microphysics schemes (including 4-ICE and spectral bin scheme) for a wide range of precipitation systems (e.g., scattered versus organized convective systems and lake effect versus synoptic snow events) in different geophysical locations (e.g., Iowa, Oklahoma, and Canada).

To provide model simulated cloud and precipitation data for GPM algorithm developers.

NASA Cloud Resolving Models

(Tao et al. 2009; 2014)

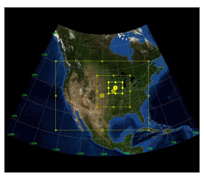
- **Multi-scale modeling system developed at Goddard with unified physics** from:
  1. **Goddard Cumulus Ensemble model** (GCE), a cloud-resolving model (CRM)
  2. **NASA unified Weather Research and Forecasting Model** (WRF), a region-scale model, and
  3. Coupled fvGCM-GCE, the GCE coupled to a general circulation model (or GCM known as **Goddard Multi-scale Modeling Framework or MMF**).
- Same parameterization schemes all of the models for cloud microphysical processes, long- and short-wave radiative transfer, and land-surface processes, to study explicit cloud-radiation and cloud-surface interactive processes.
- ***Coupled with multi-sensor simulators for comparison and validation of NASA high-resolution satellite data.***



LIS: Land Information System (data assimilation and land surface models)
GOCART: Goddard Chemistry Aerosol Radiation and Transport Model

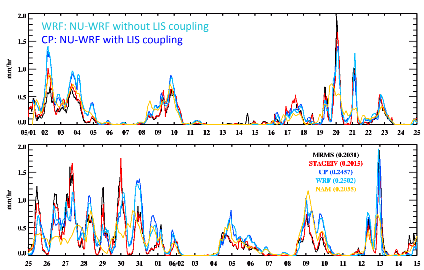
Website for mesoscale modeling group and cloud library
http://cloud.gsfc.nasa.gov/

IFloodS Real-time Forecast

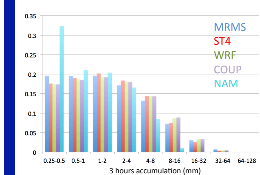


Three domains (**9km, 3km, 1km**) with **60 vertical layers.**
Physics schemes: Goddard Microphysics scheme, Grell-Devenyi ensemble cumulus scheme, Goddard Radiation schemes, MYJ planetary boundary layer scheme, Noah surface scheme, Eta surface layer scheme, NAM (18km) as input
Computational Cost: **2048 CPUs, takes 7 hours to produce 48 hours forecast.**

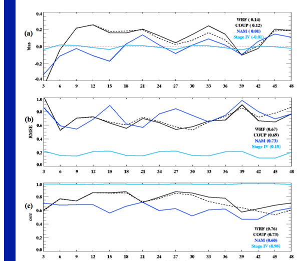
Wu, D., C. Peters-Lidard, W.-K. Tao, W. Petersen (2015): Evaluation of NU-WRF rainfall forecasts for IFloodS, J hydrometeor (submitted)



NU-WRF has overestimated rainfall. NAM has some difficulties in forecasting rainfall events during 5/25-6/3.



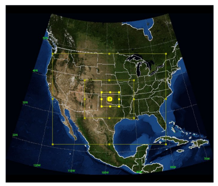
- All datasets are on 12 km grid.
- NAM overestimate light rain frequency, but underestimate heavy rain frequency.
- Two NU-WRF runs have very close PDF distribution.



WRF (solid): NU-WRF without LIS
COUP (dash): NU-WRF with LIS

- MRMS as reference data
- Based on 3 hours accumulation (mm)
- NAM has low Bias, high RMSE, and low correlation compare with NU-WRF.
- WRF has high bias, low RMSE, and high correlation compare with COUP.

MC3E Real-time forecast

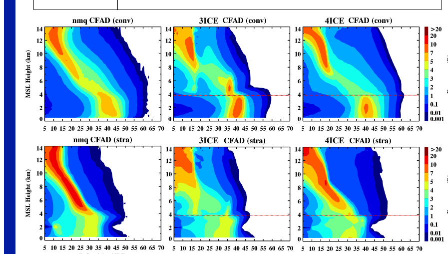


Three nested domain (**18km, 6km, 2km**) with **40 vertical layers**.
Physics: Goddard Microphysics scheme, Grell-Devenyi ensemble cumulus scheme, Goddard Radiation schemes, MYJ planetary boundary layer scheme, Noah surface scheme, Eta surface layer scheme.
Computational Cost: **240 CPUs, takes 4 hours to produce 48 hours forecast.**

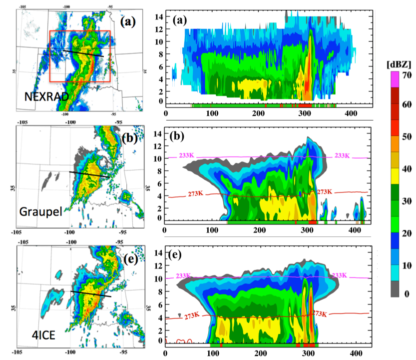
Tao, W.-K., D. Wu, T. Matsui, C. Peters-Lidard, S. Lang, A. Hou, M. Rienecker (2013): The Diurnal Variation of Precipitation during MC3E: A Numerical Study, *J. Geophys. Res. Atmos.*, **118**, 7199–7218.

Tao, W.-K., D. Wu, S. Lang, T. Iguchi, C. Peters-Lidard, A. Fridlind, and T. Matsui (2015): High-resolution NU-WRF simulations of a deep convective-precipitation system during MC3E: Part I: Comparisons between Goddard microphysics schemes and observations, *J. Geophys. Res. Atmos.*(Accepted).

Run	Microphysics
Graupel	3ICE scheme with graupel option and 1 km horizontal grid
Hail	3ICE scheme with hail option and 1 km horizontal grid
4ICE_v0	Original 4ICE scheme and 1 km horizontal grid
4ICE	Modified 4ICE scheme and 1 km horizontal grid
4ICE_nec	Modified 4ICE scheme but no rain evaporation correction, 1 km horizontal grid



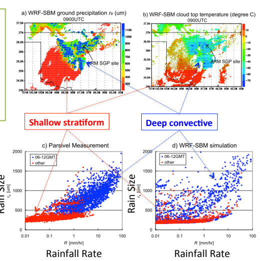
The observed high frequency region decrease their reflectivity values with increase of height in a linear fashion in both stratiform and convective region. 4ICE best captures observed features for both high frequency region (due to improved snow mapping) and reflectivity peak value in convective region (due to inclusion of hail category).

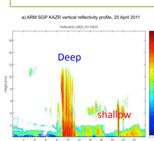


4ICE produces a more organized system with a longer, more continuous line of leading convection that has a slightly bowed structure and a broader stratiform area with a more defined transition region separating it from the leading convection. Vertical cross-section shows a more pronounced transition zone aloft and even more vertically-stratified echoes with a sharper vertical gradient in the trailing stratiform region due to an larger aggregation effect in the prescribed snow size mapping scheme.

Two-Mode Surface DSD in MC3E

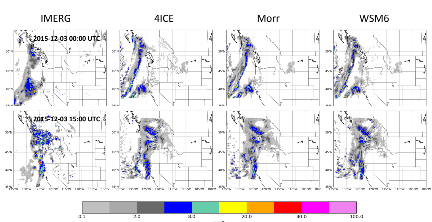
1. KAZR and Parsivel revealed two distinct modes of DSD in shallow and deep convective cell within single precipitation system, and WRF-SBM simulation captured them.
2. WRF-SBM datasets are used to generate the simulated GPM orbital testbed through the GPM Simulator.

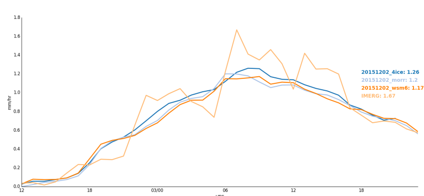




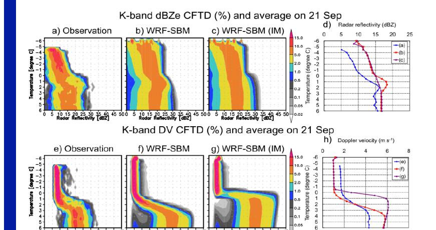
Iguchi, T., T. Matsui, A. Tokay, P. Kollias, and W.-K. Tao (2012), Two distinct modes in one-day rainfall event during MC3E field campaign: Analyses of disdrometer observations and WRF-SBM simulation. *Geophysical Research Letters*, 39, L24805, doi:10.1029/2012GL053329.

OLYMPEX



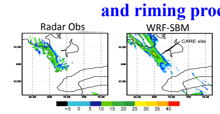


Melting Band in LPVEx

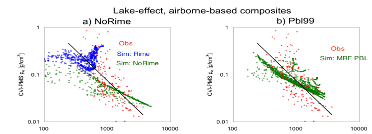


Iguchi, T., T. Matsui, W.-K. Tao, A. P. Khain, V. T. J. Phillips, C. Kidd, T. L'Ecuyer, S. A. Braun, and A. Hou (2014), WRF-SBM simulations of melting layer structure in mixed-phase precipitation events observed during LPVEx, *Journal of Applied Meteorology and Climatology*, (In press). e-View doi: http://dx.doi.org/10.1175/JAMC-D-13-0334.1

Sensitivity of PBL to super-cooled water and riming process in C3VP



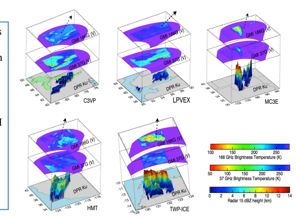
1. WRF-SBM captured structure of lake-effect snow storm.
2. Detailed analysis of SBM microphysics and aircraft observations revealed the large sensitivity of PBL scheme to mixed-phase microphysics.



Iguchi T., T. Matsui, J. J. Shi, W.-K. Tao, A. P. Khain, A. Hou, R. Cifelli, A. Heymsfield, and A. Tokay (2012), Numerical analysis using WRF-SBM for the cloud microphysical structures in the C3VP field campaign: Impacts of supercooled droplets and resultant riming on snow microphysics, *Journal of Geophyiscal Research*, 117, D23206, doi:10.1029/2012JD018101.

Synthetic GPM Simulator

1. WRF-SBM simulations were used to generate observable signals from the GPM satellite before launching.
2. Supporting algorithm development, and GPM simulator (forward model) will support CRM evaluation/ development and data assimilation.



Matsui, T. T. Iguchi, X. Li, M. Han, W.-K. Tao, W. Petersen, T. L'Ecuyer, R. Meneghini, W. Olson, C. D. Kummerow, A. Y. Hou, M. R. Schwaller, E. F. Stocker, J. Kwiatkowski (2013), GPM satellite simulator over ground validation sites, Bulletin of the American Meteorological Society 2013 ; e-View doi: http://dx.doi.org/10.1175/BAMS-D-12-00160.1

Summary and Future Works

- NU-WRF simulations can capture the basic characteristics of mid-latitude and high-latitude precipitation events.
- The Goddard 4-ICE scheme significantly improves the structure, CFADs (especially for higher dBZ aloft) compared to the 3-ice scheme.
- Continue to support GV by conduct NU-WRF real-time forecasting
- Continue to validate the model-simulated cloud microphysical properties using ground-based, space-borne and aircraft measurements – working with CSU radar group
- Compare different WRF microphysics schemes
- Conduct sensitivity tests to identify the uncertainty of some of the microphysical processes (i.e., riming) – currently is working with CSU RAMS group